Claims

1. A method of determining a profile, comprising the steps of:

(a) providing a substrate having a repeating structure comprising a plurality of lines, said lines having substantially identical profiles;

(b) illuminating said repeating structure with radiation wherein said radiation diffracts, said diffracted radiation having an intensity;

(c) measuring said intensity;

(d) providing a model structure on a data processing machine, said model structure comprising a repeating structure on said substrate, said model structure comprising a model profile;

(e) mathematically predicting a predicted diffracted radiation intensity when said model structure is illuminated with said radiation; and

(f) comparing said predicted intensity with said measured intensity.

2. A method as recited in claim 1, further comprising the step of adjusting said model structure and repeating said steps (e) and (f) to improve agreement in said comparing step (f).

3. A method as recited in claim 1, wherein said model structure is one of a library of model structures.

4. A method as recited in claim 1, wherein said profile comprises a line edge profile.

5. A method as recited in claim 1, wherein said profile comprises a composition versus depth profile.

6. A method as recited in claim 5, wherein composition varies with depth according to a doping profile.

7. A method as recited in claim 5, wherein composition varies with depth according to layering of films on a substrate.

8. A method as recited in claim 1, wherein said lines comprise a film on said substrate, said film having a film thickness and a film index of refraction, said substrate having a substrate index of refraction.

9. A method as recited in claim 1, wherein said plurality of lines comprises at least 5 lines.

10. A method as recited in claim 1, wherein said diffracted radiation of said step (b) is reflected.

11 A method as recited in claim 1, wherein said radiation is light.

12. A method as recited in claim 11, wherein in said illuminating step (b) said light has a range of wavelengths.

13. A method as recited in claim 12, wherein said wavelength range comprises about 450nm to about 750nm.

14. A method as recited in claim 12, wherein said wavelength range comprises about 1um to about 40um.

15. A method as recited in claim 1, wherein said radiation diffracts with an intensity as a function of wavelength and, wherein, in said measuring step (c), measuring said intensity as a function of wavelength.

16. A method as recited in claim 1, wherein in said predicting step (e), mathematically predicting the intensity of radiation that would be reflected from the model as a function of wavelength.

17. A method as recited in claim 1, wherein in said illuminating step (b), illuminating said substrate at a range of incident angles near normal.

18. A method as recited in claim 17, wherein said range of incident angles is equal to or less than about 5 degrees from normal.

19. A method as recited in claim 18, wherein said illuminating step illuminates said substrate through a lens having a numerical aperture of less than about .1.

20. A method as recited in claim 1, wherein said diffracted light is measured at a fixed range of angles.

21. A method as recited in claim 20, wherein said range is equal to or less than about 5 degrees.

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22. A method as recited in claim 21, wherein light incident on said lines is reflected and diffracted by said plurality of lines into a plurality of orders including a zeroth order, further wherein, said range being set to limit measured light to said zeroth order, light in other orders being diffracted at an angle larger than said fixed range of angles.

23. A method as recited in claim 22, wherein said model further comprises an incident light wavelength range, a lens numerical aperture, a film index of refraction, and a substrate index of refraction, and wherein said line profile includes line width, edge shape, and film thickness.

24. A method as recited in claim 22, wherein said mathematical predicting step (d) comprises using the range of incident angles, the range of incident wavelengths, the range of reflected angles, and Maxwell's equations to predict the amount of light that would be reflected from the model profile.

25. A method as recited in claim 24, wherein said lines comprise one of photoresist lines, metal lines, insulator lines, multiple composite stacks, planarized embedded profiles, and phase-shift masks.

26. A method as recited in claim 24, further comprising the step of adjusting said model structure and repeating said steps (e) and (f) to improve agreement in said comparing step (f) until said predicted intensity and said measured intensity agree within a convergence limit, wherein, after said convergence is achieved said model line profile describes said line profile.

27. A method of determining the profile of a repeating structure comprising the steps of:

(a) providing a substrate having a plurality of lines having substantially identical line profiles and spacings;

(b) illuminating said lines with radiation having a range of wavelengths, wherein said radiation reflects with an intensity as a function of wavelength;

(c) measuring the intensity of radiation reflected from said lines as a function of wavelength;

(d) providing a model of the line profile and line spacing;

(e) mathematically predicting the intensity of radiation that would be reflected from the model as a function of wavelength; and

(f) comparing the predicted intensity with the measured intensity; and

(g) adjusting the model and repeating steps (e) and (f) to improve agreement in said comparing step (f).

28. An apparatus for determining the profile of a line on a substrate, the apparatus comprising:

a radiation source for illuminating the substrate with radiation, said substrate comprising a repeating structure, said repeating structure comprising a plurality of lines and spaces between said lines, said lines having substantially the same line profile, said spaces being substantially identical, the illuminating of the repeating structure for obtaining diffraction of said radiation, wherein said diffracted radiation has an intensity;

a polarizer for selecting a single polarization of light of incident or diffracted light;

a detector for measuring said intensity;

a data processing machine comprising a computer model structure, said model structure comprising a model repeating structure on a model substrate, said repeating structure comprising a plurality of model lines and model spaces between said model lines, said model lines having substantially the same model line profile, said model spaces being substantially identical, said data processing machine for mathematically predicting a predicted diffracted radiation intensity when said model structure is illuminated with said radiation source;

said data processing machine further comprising means for comparing said predicted intensity with said measured intensity; and

said data processing machine further comprising means for adjusting said model structure and for repeating said predicting and comparing steps to improve agreement in said comparing step.